CLAIMS

What is claimed is:

1. A method of adjusting a spatial and temporal profile of process conditions of a substrate during processing, the method being performed using a process apparatus and a controller, the controller and process apparatus being coupled so the controller is capable of controlling the spatial and temporal profile of process conditions experienced by the substrate, the controller being capable of using at least one control parameter, the method comprising the steps of:

i. constructing a perturbation model that relates changes in the control parameters to resulting changes in the spatial and temporal profile of process conditions experienced by the substrate;
ii. using the perturbation model with at least one of a performance objective and a constraint to derive optimized control parameters; and
iii. operating the controller with the optimized control parameters.

2. The method of claim 1 wherein the process comprises a process used for fabricating integrated circuits on semiconductor wafers.

3. The method of claim 1 wherein the process is selected from the group consisting of photolithography, plasma etch, chemical vapor deposition, thermal anneal, ion implantation, post exposure bake, and physical vapor deposition.

4. The method of claim 1 wherein the perturbation model comprises a linear model for small changes in the spatial and temporal profile of process conditions.

5. The method of claim 1 wherein the perturbation model comprises a nonlinear model for large changes in the spatial and temporal profile of process conditions.

6. The method of claim 1 wherein the optimized control parameters are derived using the performance objective and the constraint.

7. The method of claim 1 wherein the process includes a transient regime and a near steady-state regime and the optimized control parameters are derived in order to optimize at least one of

the transient regime and

the near steady-state regime.

8. The method of claim 1 wherein the substrate sensitive process includes a transient regime and a near steady-state regime and the optimized control parameters are derived in order to optimize the transient regime.

9. The method of claim 1 wherein the process includes a transient period and a near steady-state regime and the optimized control parameters are derived in order to optimize the near steady-state regime.

10. The method of claim 1 wherein the step of constructing the perturbation model comprises

a) measuring baseline control parameter values α_0 comprising spatially resolved and time resolved conditions of the form $T_0(x,y,t)$;

b) acquiring data for a perturbation model for a number, N, of control parameters, N being at least 1, by performing a minimum of N condition profile measurements, wherein each profile results from perturbing one or more of the control parameters until each of the control parameters has been perturbed; and

c) constructing the perturbation model by aligning and synchronizing the profile data so that the data share the same time scale to allow representing the perturbation model as

$$T(x,y,t) = T_o(x,y,t) + \sum_{i=1}^{N} B_i(x,y,t)\Delta\alpha(i)$$

wherein the functions $B_i(x,y,t)$ are basis functions in the perturbation model, and $\Delta\alpha(i)$ are the perturbations in the i^{th} control parameter from nominal $\alpha_0(i)$ and estimating the basis functions using the data from step b) to complete the perturbation model.

11. The method of claim 1 wherein step iii comprises
    a) measuring an initial conditions profile of time resolved and spatially resolved data;
    b) providing a predetermined performance objective and a constraint;
    c) calculating adjustments for the control parameters using the initial profile, the performance objective, the constraint, and the perturbation model; and
    d) adjusting the control parameters in the controller and using the adjustments so as to provide the optimized control parameters.

12. The method of claim 1 wherein the spatial and temporal profile comprises at least one of temperature, plasma potential, ion energy, ion density, and heat flux for the substrate in a glow discharge plasma process.

13. The method of claim 1 wherein the spatial and temporal profile comprises temperature of the substrate in a glow discharge plasma process.

14. The method of claim 1 wherein the substrate is selected from the group consisting of semiconductor wafer, flatpanel display, and photolithography mask.

15. A method of controlling temperature profiles of substrates for post exposure bake processes, the method being performed using a heating device and a controller, the controller and heating device being coupled so the controller is capable of controlling the temperature of the heating device, the controller being capable of using at least one control parameter, the method comprising the steps of:

a) measuring baseline control parameter values α_0 comprising spatially resolved and time resolved temperature data of the form $T_0(x,y,t)$;

b) acquiring data for a perturbation model for a number, N, of control parameters, N being at least 1, by performing a minimum of N temperature profile measurements, wherein each temperature profile results from perturbing one or more of the control parameters until each of the control parameters has been perturbed;

c) constructing the perturbation model by aligning and synchronizing the temperature profile data so that the data share the same time scale to allow representing the perturbation model as

$$T(x,y,t) = T_o(x,y,t) + \sum_{i=1}^{N} B_i(x,y,t)\Delta\alpha(i)$$

where the functions $B_i(x,y,t)$ are basis functions in the perturbation model, and $\Delta\alpha(i)$ are the perturbations in the i^{th} control parameter from nominal $\alpha_0(i)$ and estimating the basis functions using the data from step b) to complete the perturbation model;

d) measuring an initial temperature profile, $T_S(x,y,t)$ of time resolved and spatially resolved temperature data;

e) providing a predetermined performance objective $J(T(x,y,t))$ and constraints C;

f) calculating adjustments for the control parameters using the initial temperature profile, the performance objective, the constraints, and the perturbation model;

g) adjusting the control parameters in the controller using the adjustments so as to provide updated control parameters; and

h) controlling the temperature of the substrates for post exposure bake processes using the updated control parameters.

16. The method of claim 15 wherein estimating the basis functions in step c) includes using least squares calculations on the data obtained in steps b) for the equation

$$T_k(x,y,t) = T_o(x,y,t) + \sum_{i=1}^{N} B_i(x,y,t)\Delta\alpha_k(i)$$

for k = 1, 2, ... M and $\Delta\alpha_k(i) = \alpha_k(i) - \alpha_0(i)$ and choosing the basis function Bi(x,y,t) to minimize the equation

$$\sum_{k=1}^{M} \| T_k(x,y,t) - T_o(x,y,t) - \sum_{i=1}^{N} B_i(x,y,t)\Delta\alpha_k(i) \|^2 .$$

17. The method of claim 15 further comprising repeating steps a) to h) using the updated control parameters and a temperature profile produced using the updated control parameters to provide further updated control parameters.

18. In a combination,

a controller operable with a number N of updated control parameters where N is at least one; and

a substrate processing chamber comprising a heating device coupled to the controller to allow the controller to control the temperature of the heating device;

wherein the updated control parameters are derived by the steps of:

a) providing baseline control parameter values α_0 comprising spatially resolved and time resolved temperature data of the form $T_0(x,y,t)$ for the heating device;
b) acquiring data for a perturbation model for a number, N, of control parameters, N being at least 1, by performing a minimum of N temperature profile measurements, wherein each temperature profile results from perturbing one or more of the control parameters until each of the control parameters has been perturbed;
c) constructing the perturbation model by aligning and synchronizing the temperature profile data so that the data share the same time scale to allow representing the perturbation model as

$$T(x,y,t) = T_o(x,y,t) + \sum_{i=1}^{N} B_i(x,y,t)\Delta\alpha(i)$$

d) where the functions $B_i(x,y,t)$ are basis functions in the perturbation model, and $\Delta\alpha(i)$ are the perturbations in the i^{th} control parameter from nominal $\alpha_0(i)$ and estimating the basis functions using the data from step b) to complete the perturbation model;

e) measuring an initial temperature profile, $T_S(x,y,t)$ of time resolved and spatially resolved temperature data;

f) providing a predetermined performance objective J(T(x,y,t)) and constraints C;

g) calculating adjustments for the control parameters using the initial temperature profile, the performance objective, the constraints, and the perturbation model; and

h) adjusting the control parameters in the controller using the adjustments so as to provide the updated control parameters for the controller.

19. The combination of claim 18, wherein the chamber is configured for processing a semiconductor wafer.

20. The combination of claim 18, wherein the chamber is configured for plasma etch processes, chemical vapor deposition processes, rapid thermal anneal processes, post exposure bake processes, or ion implantation processes

21. The combination of claim 18, wherein the chamber is configured so as to be capable of processing a semiconductor wafer, a lithography mask, or a flat panel display.